Effect of endodontic access simulation on the fracture strength of lithium-disilicate and resin-matrix ceramic CAD-CAM crowns

Oguz, Ece İrem ; Kılıçarslan, Mehmet Ali ; Özcan, Mutlu

Abstract: OBJECTIVES The purpose of this in vitro study was to compare the effect of simulated endodontic access preparation on the failure loads of lithium disilicate crowns and resin-matrix ceramic (RMC) crowns. MATERIALS AND METHODS Eighty maxillary first premolar crowns were manufactured by using four different CAD/CAM blocks (n = 20): lithium disilicate (LD; IPS e.max CAD), resin nanoceramic (RNC; Lava Ultimate), flexible nanaoceramic (FNC; GC Cerasmart), and polymer-infiltrated ceramic (PIC; VITA Enamic). Half of each group was accessed and repaired to simulate endodontic treatment. After cyclic loading, all specimens were loaded to failure. Data were analyzed with two-way ANOVA followed by Tukey-HSD test (α = .05). RESULTS The load to failure results showed significant differences for material types (P < .001), but not for endodontic access simulation (P = .09). The highest and lowest mean failure loads were obtained for LD (1546 N) and PIC (843 N), respectively. CONCLUSION The endodontic access preparation was not found to affect the fracture strength of LD and RMC crowns. The LD showed higher fracture strength than RMC crowns. Even though significant differences were noted for failure loads regarding different crown materials, all could reasonably withstand masticatory forces. CLINICAL SIGNIFICANCE The endodontic access preparation through a restoration is known to be a common challenge in clinical practice. Maintaining a repaired LD or RMC crown is feasible and replacement may not be necessary.

DOI: https://doi.org/10.1111/jerd.12591

Originally published at:
Oguz, Ece İrem; Kılıçarslan, Mehmet Ali; Özcan, Mutlu (2020). Effect of endodontic access simulation on the fracture strength of lithium-disilicate and resin-matrix ceramic CAD-CAM crowns. Journal of Esthetic and Restorative Dentistry, 32(5):472-479.
DOI: https://doi.org/10.1111/jerd.12591

Effect of endodontic access simulation on the fracture strength of

lithium-disilicate and resin-matrix ceramic CAD-CAM crowns

Ece İrem Oguz, DDS[1], Mehmet Ali Kılıcarslan,DDS, PhD,[1] Mutlu Özcan, DDS, FADM, FICD, FDS RCPS, PhD[2]

[1]Department of Prosthodontics, Faculty of Dentistry, Ankara University, Ankara, Turkey.

[2]Department of dental materials, Faculty of Dental Medicine, University of Zurich, Zurich, Switzerland.

Ece Irem Oguz, Lecturer, Prosthodontist, Department of Prosthodontics, Faculty of Dentistry, Ankara University, Ankara, Turkey.

Mehmet Ali Kılıçarslan, Professor, Vice Dean, Department of Prosthodontics, Faculty of Dentistry, Ankara University, Ankara, Turkey.

Mutlu Özcan, Professor, Department of Dental Materials, Faculty of Dental Medicine, University of Zurich, Zurich, Switzerland.

Corresponding author:

Dr. Ece Irem Oğuz

Department of Prosthodontics, Faculty of Dentistry, Ankara University

Emniyet mah. Incitas sok. 06560

Yenimahalle, Ankara, Turkey

Phone:+90 533 388 80 29

Email: eikiyan@ankara.edu.tr

ACKNOWLEDGMENTS

The authors of this study thank Prof. Dr. Ensar Baspinar for his support as the statistical analyzer, Prof. Dr. Alp Can and Mr. Çağlayan Güneş for the SEM analysis, Mr. Şenol Deniz for the academic editing of the paper, Mr. Mustafa Yeşil for his support as laboratory technician, and GC Dental Products Company for their materials support. The equipment used in this research was supplied by Ankara University Scientific Research Projects Coordination Unit. Project Number: 14A0234001. The authors do not have any financial interest in the companies whose materials are included in this article.

Abstract

Objectives: The purpose of this in vitro study was to compare the effect of simulated endodontic access preparation on the failure loads of lithium disilicate crowns and resin-matrix ceramic (RMC) crowns.

Materials and methods: Eighty maxillary first premolar crowns were manufactured by using four different CAD/CAM blocks (n=20): lithium disilicate (LD; IPS e.max CAD), resin nanoceramic (RNC; Lava Ultimate), flexible nanaoceramic (FNC; GC Cerasmart), and polymer-infiltrated ceramic (PIC; VITA Enamic). Half of each group was accessed and repaired to simulate endodontic treatment. After cyclic loading, all specimens were loaded to failure. Data were analyzed with 2-way ANOVA followed by Tukey-HSD test ($\alpha = 0.05$).

Results: The load to failure results showed significant differences for material types ($P<0.001$), but not for endodontic access simulation ($P=0.09$). The highest and lowest mean failure loads were obtained for LD (1546N) and PIC (843N), respectively.

Conclusion: The endodontic access preparation was not found affect the fracture strength of LD and RMC crowns. The LD showed higher fracture strength than RMC crowns. Even though significant differences were noted for failure loads regarding different crown materials, all could reasonably withstand masticatory forces.

Clinical Significance: The endodontic access preparation through a restoration is known to be a common challenge in clinical practice. Maintaining a repaired LD or RMC crown is feasible and replacement may not be necessary.

KEYWORDS: CAD/CAM, lithium disilicate, resin-matrix ceramic, fracture strength, root canal treatment

1 / INTRODUCTION

Endodontic treatment requirement for a tooth after receiving a complete coverage restoration is undesired, yet not uncommon. The incidence of a need for an endodontic treatment in fixed prosthodontics ranges from 0,7% to 21%.[1] Once the endodontic treatment is indicated, the decision either by performing an access through the existing crown or removing the entire restoration is based on the clinical judgement of the dentist.[2] Patients are usually for the first option; however, complications associated with performing the endodontic treatment through a crown should be considered thoroughly. First, locating the pulp chamber can be regarded as a challenging task since the crown masks the coronal tooth structure.[3] Second, the seal of the repaired access cavity is crucial to prevent microleakage, thus ensuring the long-term success of the restoration and endodontic treatment.[4,5] Last but not least, the fracture strength of the accessed crown may be compromised.[3,6] The previous studies evaluating the influence of simulated endodontic access preparation on all-ceramic crowns have reported several factors affecting the fracture strength such as the choice of luting cement,[6] the grit size of the rotary instrument used for the access preparation,[6] the repair filling method of the access cavity,[7] and as the most frequently investigated parameter, the type of all-ceramic material used.[3,6-9] Various all-ceramic materials with a simulated endodontic access cavities were investigated previously.[2,3,9,10] Wood et al.[3] investigated two types of polycrystalline ceramic materials and indicated a significant decrease in the fracture strength of the zirconia crowns after the endodontic access simulation but not in that of the alumina restorations. However, controversial results were obtained for the glass-matrix ceramic materials. While Bompolaki et al.[9] concluded that the endodontic access preparation of pressed lithium disilicate (LD) restorations resulted in a significant loss in the fracture strength, Gerogianni et al.[2] found no differences between endodontically accessed LD crowns and intact ones.

In addition to the polycrystalline and glass-matrix ceramics, all-ceramic restorative material classification has been updated with the introduction of resin-matrix ceramics (RMC).[11] Of all-ceramic CAD/CAM materials, the RMCs are favored by clinicians as they do not require a crystallization phase after the milling process, a quicker manufacturing with an increased dimensional stability of the final restoration is achieved.[12] In addition, the RMCs stand out with features consisting of rapid milling with minimal marginal chipping and prevention of abrasion of the antagonist natural dentition thanks to their low hardness values.[12,13] These advantages rendered these materials a suitable and highly preferred choice for the chairside monolithic restorations.

Currently, different types of RMCs are available with varying compositions and physical properties. The first of these materials included the resin nano-ceramics (RNC, Lava Ultimate; 3M ESPE) which are composed of a polymeric matrix reinforced by ceramic nano fillers. Another type of RMC has been introduced as the flexible nano ceramic (FNC, Cerasmart; GC) that contains nano-hybrid ceramic particles evenly distributed in the resin matrix.[12,14] A recent product of note is polymer-infiltrated ceramic (PIC, Vita Enamic; Vita Zahnfabrik, Bad Sackingen,Germany) that is procured by a different mechanism compared to the former two RMCs. This material undergoes a two-stage production process: first, a porous ceramic network is formed; second, it is infiltrated with polymer by capillary action.[15]

A considerable amount of studies evaluating glass-matrix and polycrystalline ceramic crowns have been conducted previously; however, there are no published data investigating the influence of the endodontic access simulation on newly introduced resin-matrix ceramic restorations. Therefore, the aim of the current study was to investigate the effects of simulated endodontic access on the fracture strength of LD and RMC crowns. The null hypotheses were (1) that the material type has no impact on the failure load of the restoration; and (2) that the endodontic access preparation would not affect the fracture strength.

2 / MATERIALS AND METHODS

An intact typodont tooth (#24) was prepared by following the standard guidelines for all-ceramic crown preparation.[16] A master die with the following preparation parameters is obtained: a preparation height of 4 mm, 12-degrees occlusal convergence angle, uniform 1.5 mm axial and 2 mm occlusal reduction, and a 1-mm chamfer finish line. The master die was positioned in a polyvinylchloride cylinder mold formed as the built-in aperture of the chewing simulator mounting chamber and embedded in self-curing acrylic resin (Palapress Vario; Heraeus Kulzer) to form a base. Eighty putty-wash impressions of the master die-base compound were made by 2-step impression method with polyvinyl siloxane (Variotime, Heraeus Kulzer GmbH). An autopolymerizing epoxy resin (bisphenol A–epichlorohydrin resin, propanetriol, glycidyl ethers) reported to have a similar stress distribution and elastic modulus with human dentin[17] was poured into each to produce 80 duplicated dies.

The master die was extracted from the mold and placed into a typodont model (Frasaco Dental Model; Frasaco, Germany). The digital optical impression of the master die was made by a chair-side intraoral scanner (CEREC Omnicam; Sirona Dental Systems GmbH, Germany). A virtual crown representing the anatomic contours of a maxillary first premolar was designed by the software (CEREC SW 4.6.1; Sirona Dental Systems GmbH, Germany) using the biogeneric individual design mode, ensuring a minimal crown thickness of 1,5 mm on the axial walls and 2 mm on the occlusal surface. Eighty identical crowns were milled from 4 different monolithic CAD/CAM blocks, one of which was LD and other three were RMCs. The blocks used, their material type, the manufacturer information, and their compounds are listed in Table 1. The same milling unit (Cerec MC XL; Sirona Dental Systems GmbH, Germany) was used to produce all crowns. The milled LD crowns were crystallized and glazed (IPS e.max CAD Crystall/Glaze; Ivoclar Vivadent, Liechtenstein) at the same time with 1 combined cycle (G9-P161 e-max CAD crystall/Glaze program, Programat P510; Ivoclar, Vivadent Ivoclar Vivadent, Liechtenstein) in a ceramic furnace (Programat P510; Ivoclar, Vivadent, Liechtenstein). The milled RMC crowns were finished with a 2-step polishing disc set (Vita Enamic polishing set technical; Vita Zahnfabrik, Germany) and a diamond polishing paste (Gradia Diapolisher paste; GC Corp, Europe).

The inner surface of each crown was treated according to the manufacturers recommendation for the respective CAD/CAM block material; RNC crowns were sandblasted with 30 µm silica-modified aluminium oxide particles (Rocatec Soft; 3M ESPE, USA) at 2 bars for 10 sec and the rest of the crowns were etched with hydrofluoric acid gel (Porcelain etchant, 9.5% HF; Bisco, USA) for 90 seconds. All crowns were ultrasonically cleaned in distilled water for 10 minutes. The external surfaces of dies and internal surfaces of crowns were conditioned with a single-bottle adhesive (Single Bond Universal; 3M ESPE, USA) and the cementation was completed with a dual-cure resin cement (RelyX Ultimate clicker; 3M ESPE, USA). The crowns were seated on the dies and subjected to a load of 50N for 1 minute. After removing the excess cement, the polymerization of cement was completed by using a LED curing unit (Bluephase 20i LED; Ivoclar Vivadent, Liechtenstein) at 1200 mW/cm^2 from 5 directions and for 20 seconds. Full seating of the crowns was confirmed with a stereomicroscope.

The specimens from each group were then further divided into 2 subgroups, half of the crowns remained intact (I) and half received a standardized endodontic access cavity then repaired (R) (n=10). A cylindrical shaped conservative access was marked on the first specimen and the preparation was performed following these markings. After the completion of access preparation on the first specimen, a polyvinyl siloxane sheet (CA® Foil; Scheu-Dental GmbH, Germany) was pressed on the specimen with heat and vacuum, and marked areas were perforated. Thus, a template serving as a transfer was obtained and performing a standardized endodontic access cavity was enabled. All the endodontic access preparations were performed by the same operator (E.I.O.) using a high-speed handpiece with water irrigation. A round diamond bur (801H 018 Meisinger; Hager & Meisinger GmbH, Germany) was used to form the initial access opening and perforate the restoration. The access preparation was completed with a round-end cylindrical diamond bur (881H 014 Meisinger; Hager & Meisinger GmbH, Germany), ensuring a standard cavity depth of 4 mm. A new diamond rotary instrument was used for each cavity preparation. Access cavity preparation time was recorded for each crown. A porcelain repair system (Ultradent porcelain repair kit; Ultradent Products, USA) and a nanocomposite resin (Filtek Ultimate Universal Restorative, shade A3 body; 3M ESPE, USA) was used to repair access cavities. The composite repair material was applied in two 2-mm increments and each was light-polymerized (Bluephase 20i LED; Ivoclar Vivadent, Liechtenstein) for 20 seconds. The occlusal aspect of the composite repair was made level with the external edges of access cavity. The composite resin repair and restoration surface interface was finished with coarse to superfine grain aluminum oxide disc system (Soflex XT finishing and polishing discs; 3M ESPE, USA). All specimens were stored in an incubator at %100 humidity and 37^{0}C for 24 hours. Two additional crowns, one with an access cavity and one with a repaired cavity, from each group were fabricated to perform a scanning electron microscope (SEM) analysis.

All specimens (N=80) were subjected to 1,2 million cycles of thermo-mechanical loading (TML) in a dual-axis chewing simulator (Mod Dental chewing simulator; Esetron Smart Robotechnologies, Turkey) to artificially simulate five years of clinical service.[18] The specimens were loaded perpendicularly with an occlusal load of 49 N by using a stainless steel ball with a diameter of 6 mm as an antagonist with integrated thermal cycling of 5°C to 55°C with a 60-seconds dwelling time at each temperature. The vertical axis movement was 6 mm, the vertical and horizontal speeds were 30 mm/s and 55 mm/s, respectively, and the lateral sliding was 0.3 mm towards the central fissure.

Following TML, all specimens were controlled for surface damages, fractures, marginal integrity, and premature debonding, then loaded to fracture on the occlusal surface along their long-axis at a 0.5 mm/min crosshead speed in a universal testing machine (Lloyd Instruments; UK). The end of the loading piston was a round-end 5 mm diameter stainless cylinder and was directed towards the central fissure of each crown representing opposing tooth contact, and contacted to the crown-composite repair interface for the repaired crowns.

The failure mode of each specimen was examined under a stereomicroscope (Leica MZ 12; Meyer Instruments Inc., USA) and classified into 3 groups as the Type I indicates a loss of less than half of the crown and intact die; the Type II shows half or more of the crown is displaced or lost and intact die; and the Type III indicates the crown fracture accompanied by die fracture.

The data were tested for the normality with a Kolmogorov-Smirnov test. Two-way ANOVA was used to compare the differences in fracture strength between four materials (LD, RNC, FNC, PIC) and two conditions (intact, repaired). The results of access cavity preparation time were analyzed by using One-way ANOVA. Multiple comparisons were performed by using Tukey-HSD. All statistical analyses were performed by using the statistical program R version 3.6.2, EXCEL (R Core Team 2019; Microsoft Corporation, USA).[7] The statistical significance was set at 0.05.

3 / RESULTS

The descriptive statistics (mean ±SD, minimum and maximum load values) are listed in Table 2. The mean fracture strength values ranged from 808 N (Group PIC-I) to 1553 N (group LD-I). Two-way ANOVA showed a statistical significance for the material type (LD, RNC, FNC, PIC) ($P < 0.001$); yet not for the condition (intact and repaired) ($P = 0.09$) or an interaction between material type and condition ($P = 0.6$). LD showed the highest load to failure value

(1546 N), while PIC showed the lowest (843 N) ($P < 0.05$). Mean fracture strengths for RNC and FNC were statistically insignificant (1128 and 1089 N, respectively) ($P > 0.05$; Figure 1).

Table 3 represents 1-way ANOVA results for the access cavity preparation times for each material. Preparation of the access cavity required more time for LD than the other materials. Differences were noted in the fracture modes, where LD did not exhibit any Type 1 failures (Table 4).

The SEM examination of the accessed LD crown showed extensive edge chippings on the cavity border while RMC crowns showed a minimal edge chipping (Figures 2 and 3). The figures 4 and 5 show the cavity borders of representative LD and RMC crowns repaired with composite resin. A gap formation is apparent between the edge of the LD access cavity and the composite repair material as a result of edge chipping and crack formation of LD material (Figure 4). A close fit is observed between the access cavity of RMC and the composite repair material (Figure 5).

4 / DISCUSSION

The main objective of the current in vitro study was to evaluate the effects of the endodontic access preparation on the fracture strength of LD and RMC CAD-CAM crowns. Depending on the results of this study, the first null-hypothesis that the material type has no impact on the fracture strength was rejected. On the other hand, the second null-hypothesis that the endodontic access preparation would not affect the fracture strength is validated for all tested materials.

In this in vitro study, care was taken to standardize the test conditions, thereby ensuring an objective analysis and consistency of the results. Identical crowns in thickness, geometry, and design were produced for all tested CAD/CAM materials by using the same STL data and a precise CAD/CAM system. Since providing a matching STL data by scanning the manual preparation of natural teeth with different morphological structures would not be feasible, a single typodont master die which was then replicated by using epoxy resin was used. When performing the access cavities, the exact same outline was performed by using a custom made template[2] and a 4 mm depth[6] which was considered adequate for the full perforation of the crown material was ensured by using marked cylindrical diamond burs. An artificial aging was applied by combining thermal cycling with mechanical loading to improve clinical validity of the experiment.[19] In the presence of water, extension of microcracks is facilitated, reducing failure loads of ceramics significantly.[20] Therefore, in such a study where cracks are initiated by endodontic access preparation, fatigue mechanical testing with integrated thermo-cycling is crucial in replicating clinical scenario.[2] However, a fracture load test at dry condition was applied to assess the maximum load that intact and accessed crowns could withstand. Load-to-failure testing provides information at extreme conditions, therefore the findings of this in vitro study should not be directly related to clinical conditions.[21,22] The constant compressive load was applied until failure on the occlusal surface of the crowns in vertical direction to simulate the normal occlusal relationship of maxillary first premolar[23] for which a loading pattern that is vertical and along the long axis was demonstrated.[24,25]

Regarding the effect of endodontic access cavity, differences in fracture strength of intact and repaired LD and RMC CAD/CAM crowns were not significant, suggesting that repair of the crown is feasible and replacement is not necessary. Recent studies stated no difference in fracture strength of milled LD crowns following endodontic access preparation, agreed to our results.[2,9] However, contradictory results were found for pressed lithium disilicate and zirconia crowns.[3,7,9] According to these findings, it should be noted that when evaluating effect of endodontic access cavity on fracture strength, results may differ according to crown material used.

The mean fracture load values in this study ranged from 808 N to 1553N. Those values were above the average maximum bite forces,[26,27] suggesting all crowns have fracture loads high enough to withstand masticatory forces. Above all, the mean fracture loads for all repaired groups also exceeded the mean maximum bite forces, indicating that both repaired LD and RMC crowns can be considered as serviceable.

In the present study, the highest and lowest fracture loads were obtained for LD and PIC crowns, respectively. Studies comparing the fracture strength of LD and RMC crowns indicated similar results,[12,28,29] attributing the higher fracture strength of LD to randomly oriented interlocked needle-like crystals embedded in the glassy matrix.[30] The fact that RNC and FNC showed higher fracture strength than PIC could be attributed to differences in structural compositions of these materials. RNC and FNC has similar compositions, a resin matrix structure with filler particles.[31] However; PIC has a dual-phase microstructure, with a porous ceramic network interpenetrated by resin polymers.[12] Moreover, the differences in weight of the ceramic component, resin matrix composition, filler particle dimension and distribution are shown to affect mechanical and physical properties of RMC materials.[12,29,31,32] The conclusion that may be extracted from these results is that different RMC materials do not necessarily behave similarly, and the microstructure and composition appear to play an important role.[14]

In the present study, none of the failed crowns represented fractures that can be considered as repairable. A crown with Types 1 and 2 fracture can be replaced, however Type 3 fracture involves both crown and tooth failure which can lead to complications as severe as extracting the tooth. From that point of view, Type 3 fractures should be considered as hopeless from a clinical standpoint. LD group showed no Type 1 fracture, and also were the group most commonly showing Type 3 fractures. One explanation could be the brittleness of LD crowns in contrast to shock absorbing and resilient behavior of RMCs.[12,33]

SEM images of LD crown showed large chipping extending distally from the access cavity whereas RMC crowns showed regular and limited chipping. Hardness of materials determines the ease of milling and was related to marginal chipping.[12,34,35] Low Vickers-hardness values of RMCs provide advantages of easier milling and decreased marginal chipping.[12,13,34] Reduced access preparation times and minimal chippings observed for RMC crowns can be attributed to their lower hardness than LD. The amount of chipping is related to reparability of the crowns as shown in SEM images (Figures 4 and 5). While a deep fissure was present between the repair material and LD material (Figure 4), a close fit was observed between the access cavity of RMC crown and composite (Figure 5). Intra-oral repair of RMC restorations with composite may be less visible and easier since they both contain resin in their composition.[36,37] Also, the repair bond strength of RNC was found out to be higher than that of LD.[38] The authors attributed this finding to difference in microstructure of these materials. A recent study demonstrated differences in hydrofluoric acid etching patterns between RMC and LD materials where varying amounts of dissolved areas of the matrix is observed depending on the microstructure.[39] Since RMC and LD materials differ in terms of adhesion mechanisms, such a difference in reparability with composite resin shown in SEM images may be regarded as reasonable. Repair of the access cavity is of clinical importance with regard to restoring coronal seal.[5] Since SEM images of this study are insufficient to interpret coronal seal efficiency of the repaired crowns, future studies are needed to establish the most appropriate crown and repair material for restoring coronal seal after endodontic treatment.

Even though this study conducted such a methodology that imitates clinical conditions as much as possible, the results may vary in the dynamic oral environment. Considering that only LD and 3 types of RMC CAD/CAM material are tested, artificial periodontium was not simulated and stainless steel ball was used as antagonist instead of natural teeth in thermo-mechanical aging simulation, in vivo studies are needed to test long-term performance of different CAD/CAM crowns with repaired endodontic access.

5 / CONCLUSIONS

The following conclusions could be drawn from this in vitro study:

1. The endodontic access cavity did not decrease the fracture strength of milled LD and RMC crowns, suggesting that both were repairable and serviceable.
2. All of the tested CAD/CAM materials yielded durable restorations at high masticatory forces.
3. The fracture strength of the LD crowns was higher than that of all types of RMCs. The lowest fracture strength was obtained for PIC crowns.
4. The endodontic access preparation resulted in large and hard to restore edge chippings in the LD crowns.
5. Preparation of the endodontic access required longer time for LD than RMC crowns.

REFERENCES

1. Goodacre CJ, Bernal G, Rungcharassaeng K, et al. Clinical complications in fixed prosthodontics. J Prosthet Dent. 2003;90(1):31-41.

2. Gerogianni P, Lien W, Bompolaki D, et al. Fracture resistance of pressed and milled lithium disilicate anterior complete coverage restorations following endodontic access preparation. J Prosthodont. 2019;28(2):163-70.

3. Wood KC, Berzins DW, Luo Q, et al. Resistance to fracture of two all-ceramic crown materials following endodontic access. J Prosthet Dent. 2006;95(1):33-41.

4. Trautmann G, Gutmann JL, Nunn ME, Witherspoon DE, Shulman JD. Restoring teeth that are endodontically treated through existing crowns. Part II: survey of restorative materials commonly used. Quintessence Int. 2000;31:719-28.

5. Al-Maqtari AA, Lui JL. Effect of aging on coronal microleakage in access cavities through metal ceramic crowns restored with resin composites. J Prosthodont. 2010;19(5):347-56.

6. Qeblawi D, Hill T, Chlosta K. The effect of endodontic access preparation on the failure load of lithium disilicate glass-ceramic restorations. J Prosthet Dent. 2011;106(5):328-36.

7. Scioscia A, Helfers A, Soliman S, et al. Performance of Monolithic and Veneered Zirconia Crowns After Endodontic Treatment and Different Repair Strategies. Oper Dent. 2018;43(2):170-9.

8. Grobecker-Karl T, Christian M, Karl M. Effect of endodontic access cavity preparation on monolithic and ceramic veneered zirconia restorations. Quintessence Int. 2016;47(9):725-9.

9. Bompolaki D, Kontogiorgos E, Wilson JB, et al. Fracture resistance of lithium disilicate restorations after endodontic access preparation: An in vitro study. J Prosthet Dent. 2015;114(4):580-6.

10. Gorman CM, Ray NJ, Burke FM. The effect of endodontic access on all-ceramic crowns: A systematic review of in vitro studies. J Dent. 2016;53:22-9.

11. Gracis S, Thompson VP, Ferencz JL, et al. A new classification system for all-ceramic and ceramic-like restorative materials. Int J Prosthodont. 2015;28(3):227-35.

12. Furtado de Mendonca A, Shahmoradi M, Gouvea CVD, et al. Microstructural and Mechanical Characterization of CAD/CAM Materials for Monolithic Dental Restorations. J Prosthodont. 2019;28(2):e587-e94.

13. Coldea A, Swain MV, Thiel N. Mechanical properties of polymer-infiltrated-ceramic-network materials. Dent Mater. 2013;29(4):419-26.

14. Goujat A, Abouelleil H, Colon P, et al. Mechanical properties and internal fit of 4 CAD-CAM block materials. J Prosthet Dent. 2018;119(3):384-9.

15. Della Bona A, Corazza PH, Zhang Y. Characterization of a polymer-infiltrated ceramic-network material. Dent Mater. 2014;30(5):564-9.

16. Rosenstiel SF, Land MF, Fujimoto J. Contemporary fixed prosthodontics. 4th ed. St. Louis: Mosby; 2016. p. 326-7.

17. Yucel MT, Yondem I, Aykent F, et al. Influence of the supporting die structures on the fracture strength of all-ceramic materials. Clin Oral Invest. 2012;16(4):1105-10.

18. Kern M, Strub JR, Lü XY. Wear of composite resin veneering materials in a dual-axis chewing simulator. J Oral Rehabil. 1999;26(5):372-8.

19. Rosentritt M, Behr M, Gebhard R, et al. Influence of stress simulation parameters on the fracture strength of all-ceramic fixed-partial dentures. Dent Mater. 2006;22(2):176-82.

20. Kelly JR, Rungruanganunt P, Hunter B, et al. Development of a clinically validated bulk failure test for ceramic crowns. J Prosthet Dent. 2010;104(4):228-38.

21. Kelly JR. Clinically relevant approach to failure testing of all-ceramic restorations. J Prosthet Dent. 1999;81(6):652-61.

22. Chen SE, Park AC, Wang J, et al. Fracture resistance of various thickness e.max cad lithium disilicate crowns cemented on different supporting substrates: An in vitro study. J Prosthodont. 2019;28(9):997-1004.

23. Madini L, Acquaviva PA, Krokidis A, et al. Effect of restorative, endodontic, and fatigue treatments on the cuspal deflection of maxillary premolars subjected to different cyclic occlusal forces: an in vitro study. Int J Periodont Rest. 2015;35(2):221-9.

24. Borcic J, Anic I, Smojver I, et al. 3D finite element model and cervical lesion formation in normal occlusion and in malocclusion. J Oral Rehabil. 2005;32(7):504-10.

25. Borcic J, Antonic R, Urek MM, et al. 3-D stress analysis in first maxillary premolar. Coll Antropol. 2007;31(4):1025-1029.

26. Ferrario VF, Sforza C, Zanotti G, et al. Maximal bite forces in healthy young adults as predicted by surface electromyography. J Dent. 2004;32(6):451-7.

27. Braun S, Bantleon HP, Hnat WP, Freudenthaler JW, Marcotte MR, Johnson BE. A study of bite force, part 1: Relationship to various physical characteristics. Angle Orthod. 1995;65(5):367-72.

28. Naffah N, Ounsi H, Ozcan M, Bassal H, Salameh Z. Evaluation of the adaptation and fracture resistance of three cad-cam resin ceramics: An in vitro study. J Contemp Dent Pract. 2019;1;20(5):571-6.

29. Okada R, Asakura M, Ando A, et al. Fracture strength testing of crowns made of CAD/CAM composite resins. J Prosthodont Res. 2018;62(3):287-92.

30. Wendler M, Belli R, Valladares D, et al. Chairside CAD/CAM materials. Part 3: Cyclic fatigue parameters and lifetime predictions. Dent Mater. 2018;34(6):910-21.

31. Lauvahutanon S, Takahashi H, Shiozawa M, et al. Mechanical properties of composite resin blocks for CAD/CAM. Dent Mater J. 2014;33(5):705-10.

32. Sonmez N, Gultekin P, Turp V, et al. Evaluation of five CAD/CAM materials by microstructural characterization and mechanical tests: a comparative in vitro study. BMC Oral Health. 2018;18(1):5.

33. Ferruzzi F, Ferrairo BM, Piras FF, et al. Fatigue survival and damage modes of lithium disilicate and resin nanoceramic crowns. J Appl Oral Sci. 2019;27:e20180297.

34. Lawson NC, Bansal R, Burgess JO. Wear, strength, modulus and hardness of CAD/CAM restorative materials. Dent Mater. 2016;32(11):e275-e83.

35. Tsitrou EA, Northeast SE, van Noort R. Brittleness index of machinable dental materials and its relation to the marginal chipping factor. J Dent. 2007;35(12):897-902.

36. Ruse ND, Sadoun MJ. Resin-composite blocks for dental CAD/CAM applications. J Dent Res. 2014;93(12):1232-4.

37. Jongsma LA, Kleverlaan CJ, Feilzer AJ. Clinical success and survival of indirect resin composite crowns: results of a 3-year prospective study. Dent Mater. 2012;28(9):952-60.

38. Wahsh MM, Ghallab OH. Influence of different surface treatments on microshear bond strength of repair resin composite to two CAD/CAM esthetic restorative materials. Tanta Dent J. 2015;12(3):178-84.

39. Helbling F, Özcan M. Adhesion of resin cement to contemporary hybrid ceramic and polymeric CAD/CAM materials: Effect of conditioning methods and ageing. J Adhes Sci Technol. 2019; 3(8): 886-9021.

Table 1 Material type, brand name, compound and manufacturer list of CAD/CAM blocks used for the study.

Material type	Abbreviation	Brand name	Manufacturer	Compounds (%)
Lithium disilicate glass–ceramic	LD	IPS e.max CAD	Ivoclar, Vivadent AG	57%-80% SiO_2, 11%-19% LiO_2, 0%-13% K_2O, 0%-11% P_2O_5, 0%-8% ZrO_2, 0%-8% ZnO, 0%-5% Al_2O_3, 0%-5% MgO
Resin nano-ceramic	RNC	Lava Ultimate	3M ESPE	80 wt% nanoceramic part with silica and zirconia particles, and 20 wt% highly cross linked polymer matrix
Flexible nano-ceramic	FNC	GC Cerasmart	GC Dental Products Corp.	71 wt% silica and barium glass nanoparticles, and 29 wt% resin matrix
Polymer-infiltrated ceramic	PIC	VITA Enamic	Vita Zahnfabrik	86 wt% inorganic ceramic part (SiO_2, Al_2O_3, Na_2O,K2O, and other oxides) and 14 wt% organic polymer part (UDMA, TEGDMA)

UDMA: urethane dimethacrylate, TEGDMA: triethylene glycol dimethacrylate

Table 2 Descriptive statistics for failure loads

Group	Condition	Mean (N) ±SD	Minimum (N)	Maximum (N)
LD	I	1553.45 ±237.77	1148.38	1827.49
	R	1539.3 ±221.04	1101.63	1927.96
RNC	I	1080.32 ±193.01	812.83	1384.68
	R	1177.17 ±110.88	1057.93	1407.98
FNC	I	1021.37 ±255.08	621.89	1402.4
	R	1158.32 ±166.66	968.04	1442.25
PIC	I	808.06 ±123.52	622.3	1009.77
	R	879.17 ±160.67	622.2	1142.45

LD = Lithium disilicate, RNC = Resin nano-ceramic, FNC = Flexible nano-ceramic, PIC = Polymer-infiltrated ceramic, I= Intact, R= Repaired

Table 3 Results of access cavity preperation time (sec)

Group	Mean (sec) ±SD
LD	94.2 ±10.4*
RNC	42.7±3.09
FNC	44.4 ±3.17
PIC	45.8 ±2.25

*Statistically significant, $P < 0.05$. For test group abbreviations see Table 1.

Table 4 Distribution of fracture modes

Group	Condition	Failure modes		
		Type 1	Type 2	Type 3
LD	I	0	4	6
	R	0	2	8
RNC	I	1	5	4
	R	1	2	7
FNC	I	3	3	4
	R	2	2	6
PIC	I	2	3	5
	R	2	4	4

For test group abbreviations see Table 2.

FIGURES

Figure 1 Load to failure (N) according to material type. Columns with the same letter are not significantly different ($P > 0.05$). For test group abbreviations see Table 1.

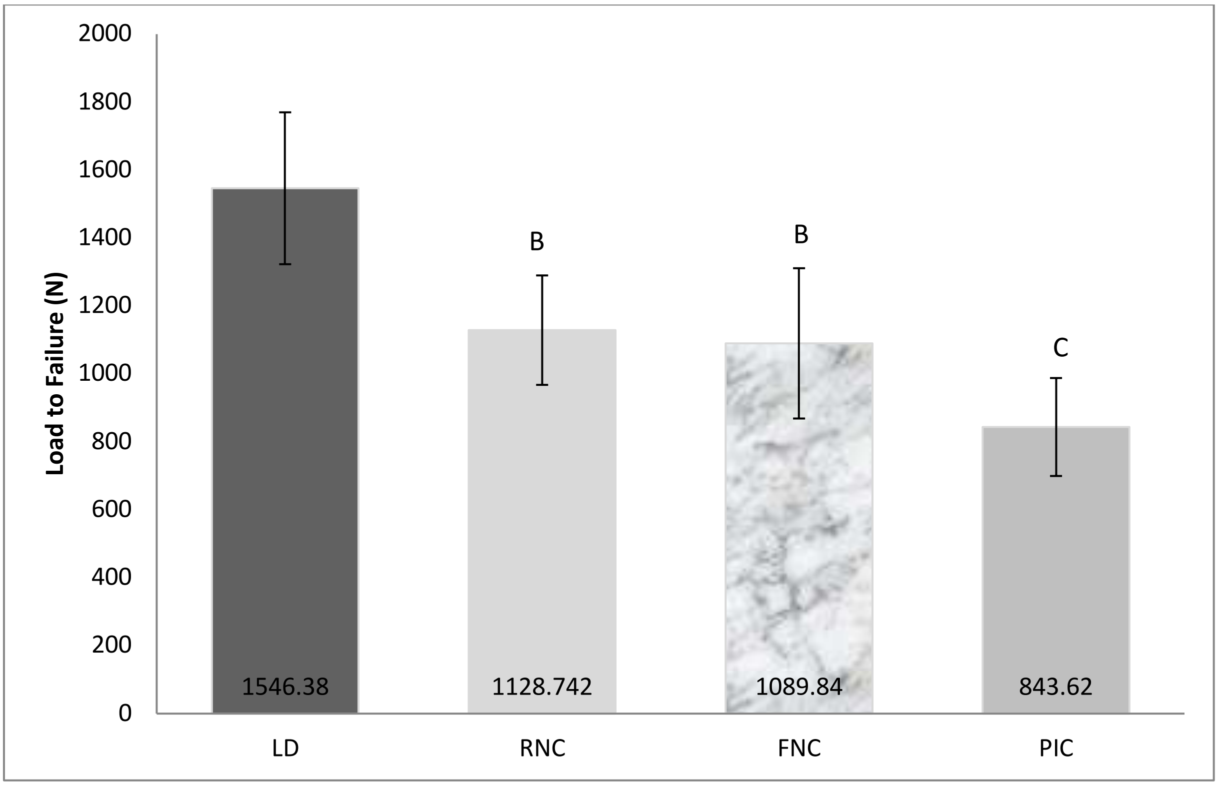

Figure 2 SEM image of an accessed LD crown showing an extensive edge chipping (×100 magnification).

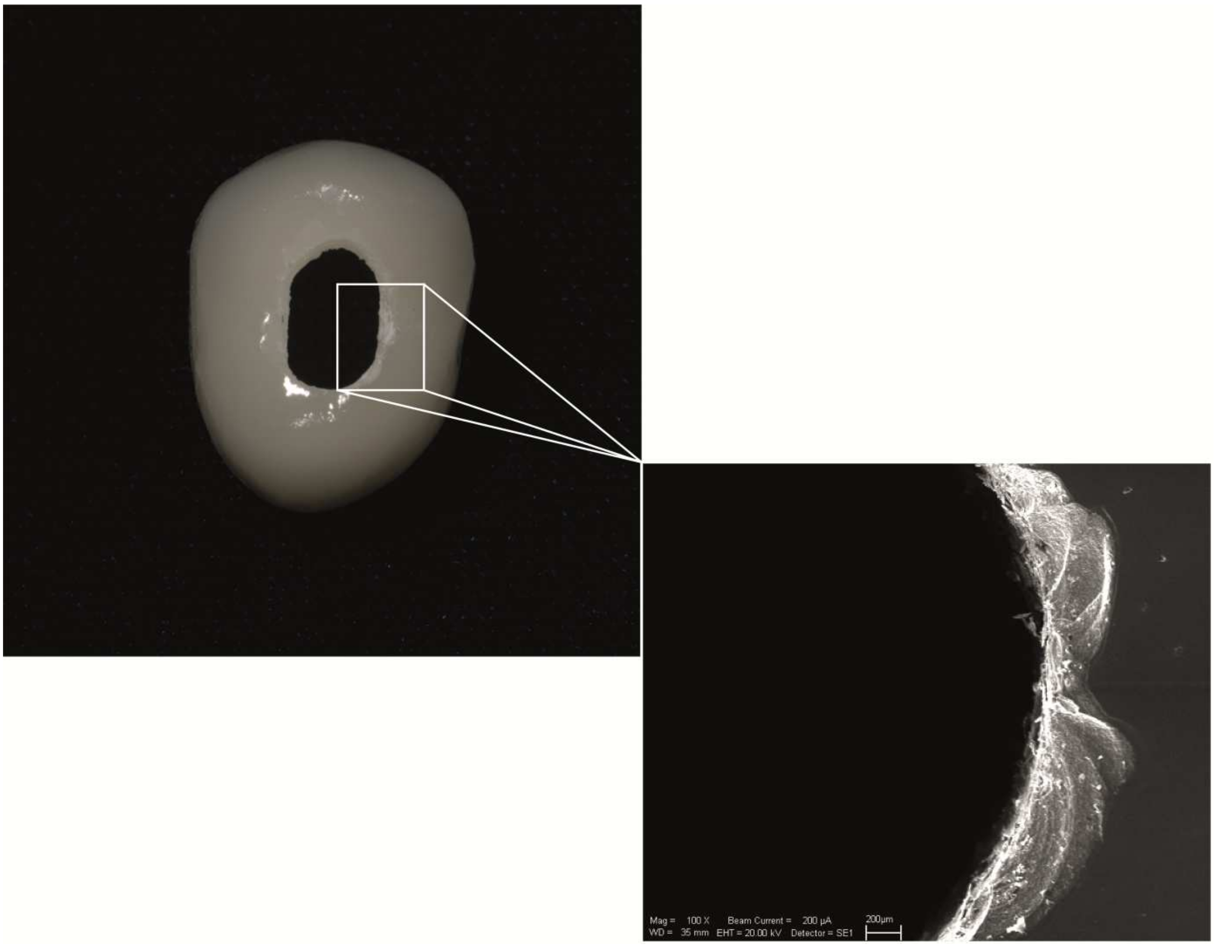

Figure 3 SEM image of an accessed RMC crown showing a minimal edge chipping (×100 magnification).

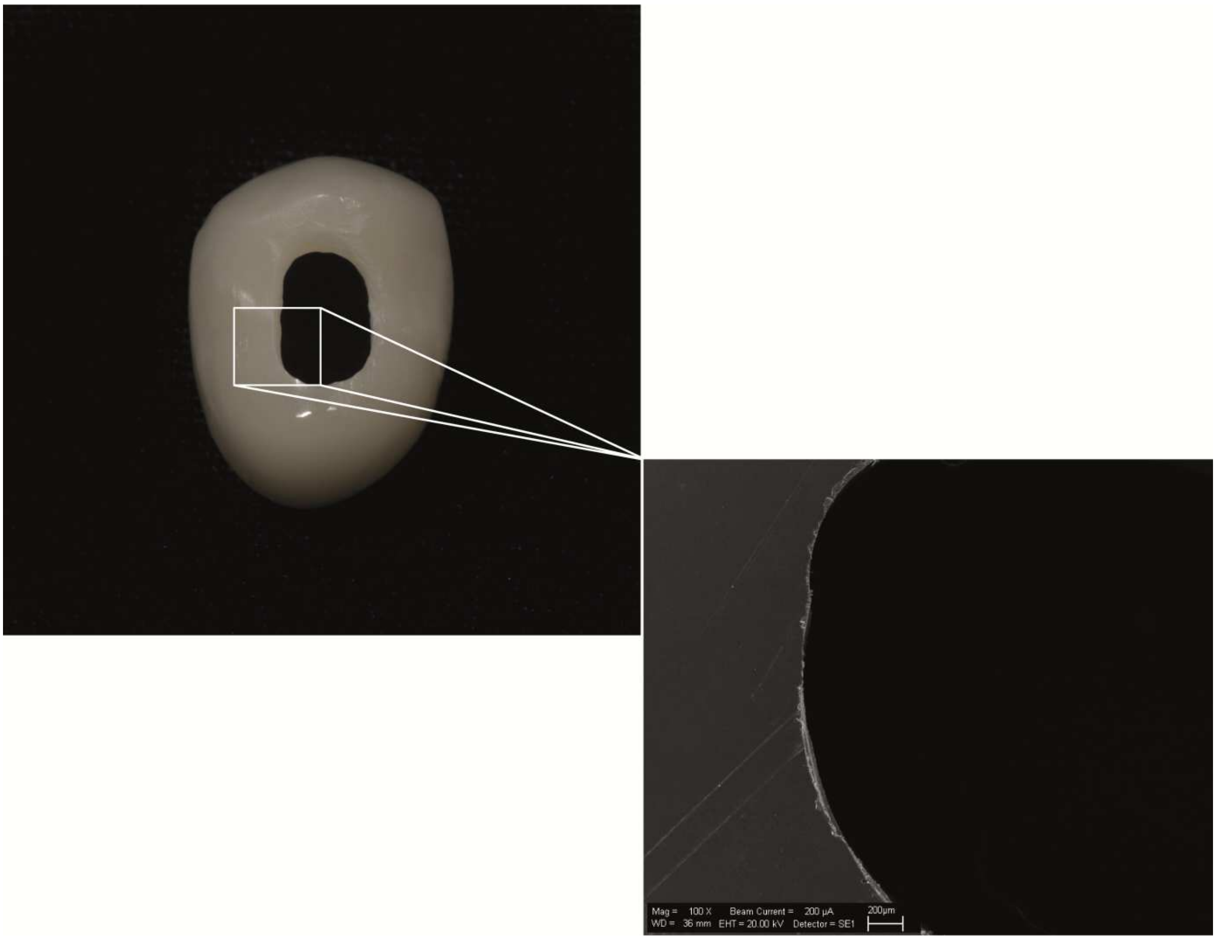

Figure 4 SEM image of a gap formation between the crack line formed on the edge of the access cavity of LD crown and composite repair material (LD: Lithium disilicate, C: Composite).

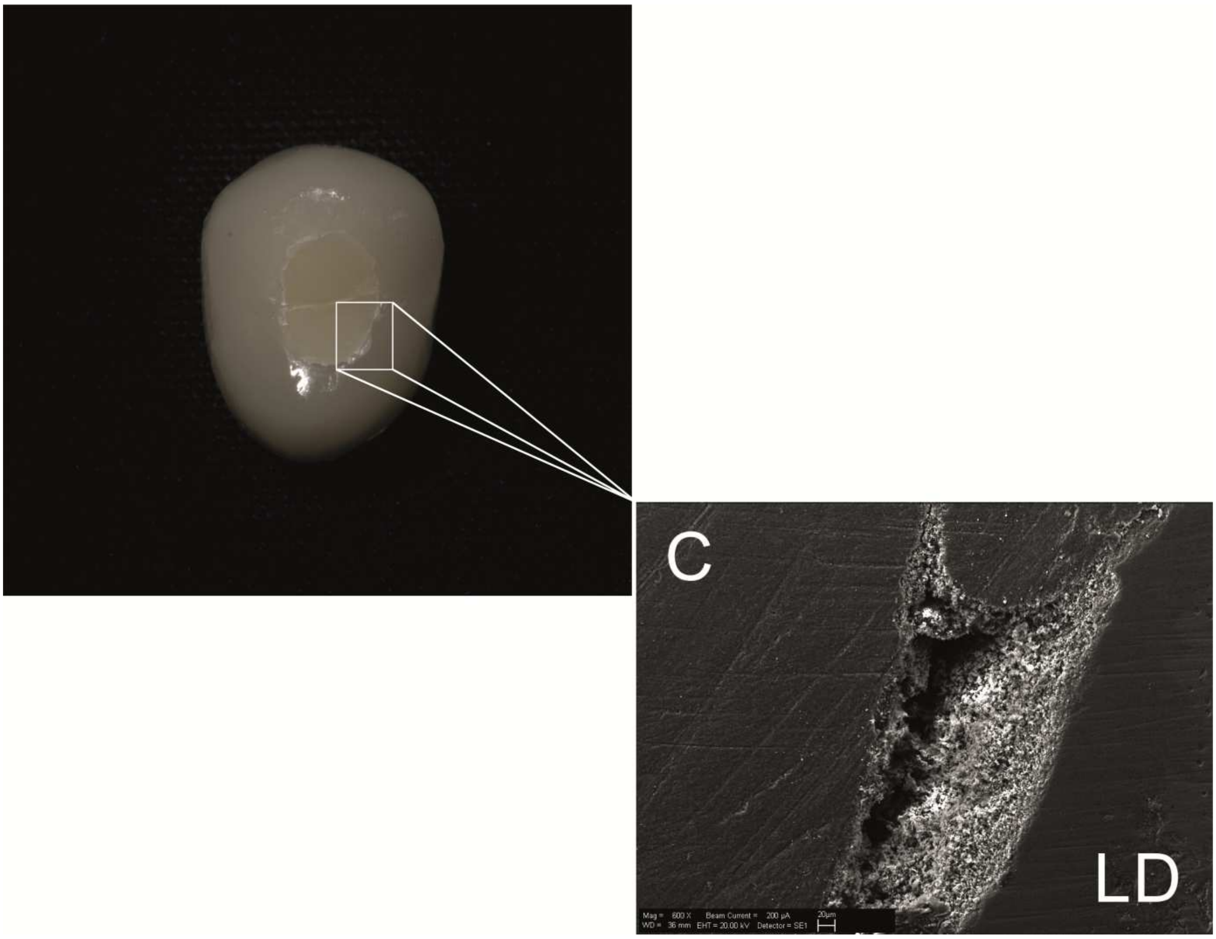

Figure 5 SEM image of close fit between the access cavity of RMC and composite repair material (RMC: resin-matrix ceramic, C: composite repair material).